

## Novel annular seven tooth antenna compare its gain and return loss with circular patch antenna for mobile navigation

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### ABSTRACT

The aim of the study involves the design of a novel annular seven tooth antenna and comparing its gain, return loss with a circular patch. Totally 38 samples are considered for the analysis which is obtained using the G power tool by fixing the pretrained power and the error rate as 0.811 and 0.051 respectively. The total 38 samples are grouped into two namely novel annular seven tooth antenna with 19 samples and circular patch with 19 samples. The performance of the antennas is analyzed using return loss and gain. The design of novel annular seven tooth antenna produced a high gain of 7.7 dB which is more significant than the gain of circular patch antennas (CPA) for navigation application. It is found that the gain, return loss of the designed novel annular seven tooth antenna is 7.7 dB, -18.1 dB. The gain and return loss of the novel annular seven tooth antenna is improved and it is compared with circular patch. It is more significant as it has a p value less than 0.05.

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## 1. INTRODUCTION

Novel annular seven tooth antenna is defined as the set of teeth with circular antennas which combine together as a single patch for transmit and receive signal [1]. The main advantage of the novel annular seven tooth antenna over a simple antenna is that the antennas radiate individually to form the radiation beam of high gain and high directivity for mobile navigation. As we increase the number of teeth the gain and directivity of the antenna increases [2]. Due to this novel annular seven tooth antenna shows better performance than a simple antenna. This research is about designing a novel annular seven tooth antenna to obtain a better gain, return loss over a circular patch for satellite service and mobile navigation applications at 4.3 GHz [3].

The proposed work-related reference papers were published in several source. In Google Scholar and Science Direct nearly 100 papers were published. FR4 epoxy used as dielectric materials for designing the patch antenna [4]. The material has a 4.4 dielectric constant. Patches can be made in a number of shapes, but the most popular ones are rectangular and circular because they are more adaptable, simple to make and analyse, have desirable properties in radiation and cross polarization [5]. For the best antenna performance, which offers stronger radiation and a higher bandwidth with the dielectric substrate thickness in mm and minimized dielectric constant [6]. Resonating frequency with dual band range of 3.1 to 10.6 GHz, and the proposed antenna has exceeded the bandwidth of ultra wideband (UWB) standards and also exhibits good

UWB features [7]. Body-centric communication uses UWB technology, and this antenna has been created for that technique. The suggested antenna satisfies both the requirements of the body area network (10 GHz band) and the satellite service communication Ku band (12 to 20 GHz) [8]. It shows how the antenna will operate during simulation. For X-band applications, this antenna design uses sapphire as the dielectric substrate. By using the microstrip feeding technique, the octagonal microstrip patch antenna's impedance matching is successfully completed [9]. The return loss, gain, and return loss value is the issue that was discovered during the analysis of the current circular patch. A novel annular seven tooth antenna with improved gain that has been constructed and compared to a circular patch is the goal of the research in order to solve this issue.

## 2. LITERATURE SURVEY

Microstrip annular ring antenna was proposed for the wireless sensor network applications with the bandwidth of 2.4 GHz. Circular type microstrip patch antenna was designed for ISM based industry, medical and scientific application with an operating frequency of 2.4 GHz [10]. Multiple input and multiple output circularly polarized antenna were developed with good insulating dielectric material for good radiation properties. Wideband frequency was obtained up to 5.37 to 6.43 GHz used for the high-speed design applications [11]. The 3×3 annular antenna was designed for retinal prosthesis applications and achieved the ultra wideband frequency of 2-11 GHz with the good impedance matching [12]. Antenna was proposed to improve the excitation power for maximizing the drift current that generates the frequency range for the high-power transfer and long-distance applications with the bandwidth of 6.5 GHz [13]. Proposed the antenna with annular microstrip feeding lines for converting the multidirectional properties of the antenna into the single array with the improved gain of 6.4 dBi with 300 MHz frequency [14]. Developed the liquid dielectric resonator antenna with the improved annular design patch with the resonating frequency of 1.8 to 2.8 GHz with the good sensitivity for air pressure applications by making the essential changes in the air pressure sensor [15]. Design of dual band rectangular microstrip patch antenna for 5.1 GHz and 5.4 GHz with improved return loss and compare with triangle antenna for WiMAX application [16]. Developed the quadratic surface based microstrip annular antenna for improved beam circularization, beam collimation and dark hollow beam generation parameters with the improved transmitting efficiency of 93.91% and wavelength of 1,550 nm for medical applications [17]. Proposed the antenna for approaching the mobile navigation applications and fixed satellite service by using the ultra wideband frequency of 4 to 14 GHz [18]. Designed the low-cost coplanar waveguide feed antenna for ultra wideband applications with the C shaped annular ring in the radiating patch with the size in millimeters and achieved the voltage standing wave ratio (VSWR) less than 2 and the bandwidth of 5.1 to 5.9 GHz [19]. Developed the dual band low profile microstrip antenna for wireless applications with the improved resonating frequency and bandwidth of 3.2 to 3.9 GHz [20].

## 3. METHOD AND MATERIALS

The size of the sample required for designing the antenna is determined using G power calculator with fixing the pretrained power and the error rate as 0.8 and 0.05 respectively [21]. The total sample size is 38. There are two groups in this proposed work. One set is considered as a novel annular seven tooth antenna and the other set is considered as a circular patch. For each set the sample size is 19. The circular patch is designed using existing systems with the aid of high frequency structure simulator (HFSS) version 15.0 software [22]. The simulation, design and execution of antennas are carried out with the help of simulation software.

The proposed work consists of a novel annular seven tooth antenna with FR4 epoxy substrate. For designing the novel annular seven tooth antenna the data was collected varying the radius of the proposed antenna and other antenna parameters like substrate thickness and its material through graphs after simulating the antenna design in the software. The proposed antenna has a significantly less voltage standing wave ratio and acceptable gain for controlling the mobile navigation. Figure 1 inferred the design and calculation parameter of the developed antenna. The design formula for annular seven tooth antenna is [23]:

$$a = F\{1 + 2h/(\pi F\epsilon_r) [\ln (\pi F/2h) + 1.7726]\} - 1/2 \quad (1)$$

Where,  $F=(8.791 \times 10^9)/(\text{fr } \sqrt{\epsilon_r})$ ;  $h=1.6$  mm;  $\pi=3.14$ ;  $\epsilon_r=4.4$

The novel annular seven tooth antenna is designed using Ansoft 15.0 version software [24]. The system requirement for processing the simulation done using Intel core i3 with 128 bits processor. The radius of the novel annular seven tooth antenna is calculated using (1).

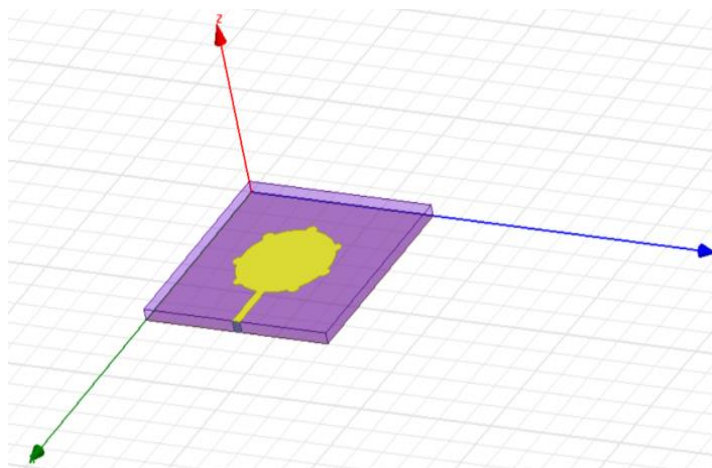


Figure 1. Schematic diagram of the novel annular seven tooth antenna by Ansoft HFSS software of length 37 mm, a width of 35.5 mm, and a height of 3.6 mm and radius 16.87 mm

#### 4. RESULTS

The performance of the novel annular seven tooth antenna and the circular patch is investigated. The dielectric constant with the radius of 4.4 cm and patch with the radius of 16.8 mm are constructed using the dielectric material of FR4 and the thickness of the substrate is equal to 1.6 mm is shown in Figure 1. The circular patch shown in Figure 2 can be obtained with the help of HFSS software with radius 16.8 mm. The gain, return loss and directivity of the antennas is calculated. Here the value of return loss is -18 for novel annular seven tooth antennas shown in Figure 3. It is obtained at a radio frequency of 4.3 GHz. Figure 4 shows the return loss of circular patch antenna (CPA) with -16.9 dB. The design of a novel annular seven tooth antenna has produced a high gain with 7.7 dB which is represented in Figure 5. Figure 6 shows circular antenna gain with 6.5 dB. Figure 7 shows the 5.37 dB of directivity is obtained during the design of annular tooth antenna which is more significant than the directivity of the existing circular patch. Figure 8 represent directivity of the circular antenna is 4.8 dB which is less significant than the directivity of the proposed annular tooth antenna. The bar graph is comparing the mean ( $\pm 1SD$ ) as shown in Figures 9 and 10.

Table 1 gives the gain, return loss value for both the groups for different values of radio frequency. The frequency range for analysis is taken between 4 GHz and 6 GHz. Group statistics of the annular tooth antenna and annular antenna optimized using the independent sample T test is inferred in Table 2. Results reveal that the significance value between the two groups is 0.01. Table 3 shows proposed work has better gain than existing work. The bar graph represents the performance of an antenna by varying the radio frequency.

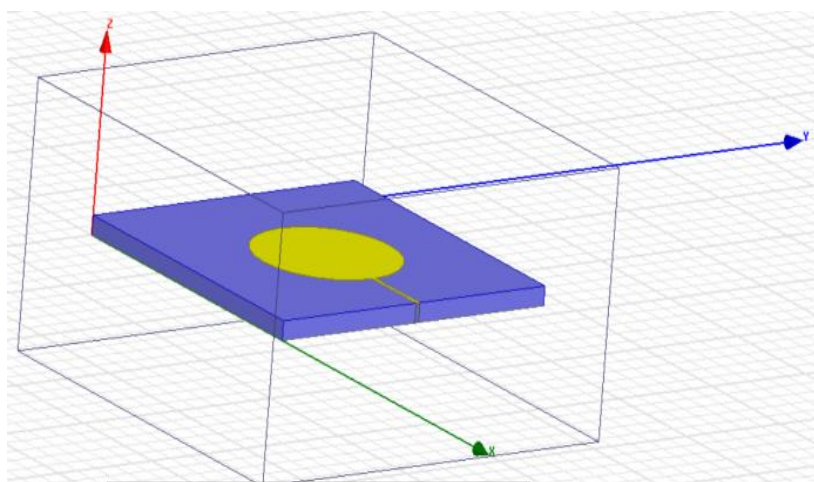


Figure 2. Schematic diagram of the CPA by Ansoft HFSS software of length 37 mm, a width of 35.5 mm, and a height of 3.6 mm and radius 16.87 mm

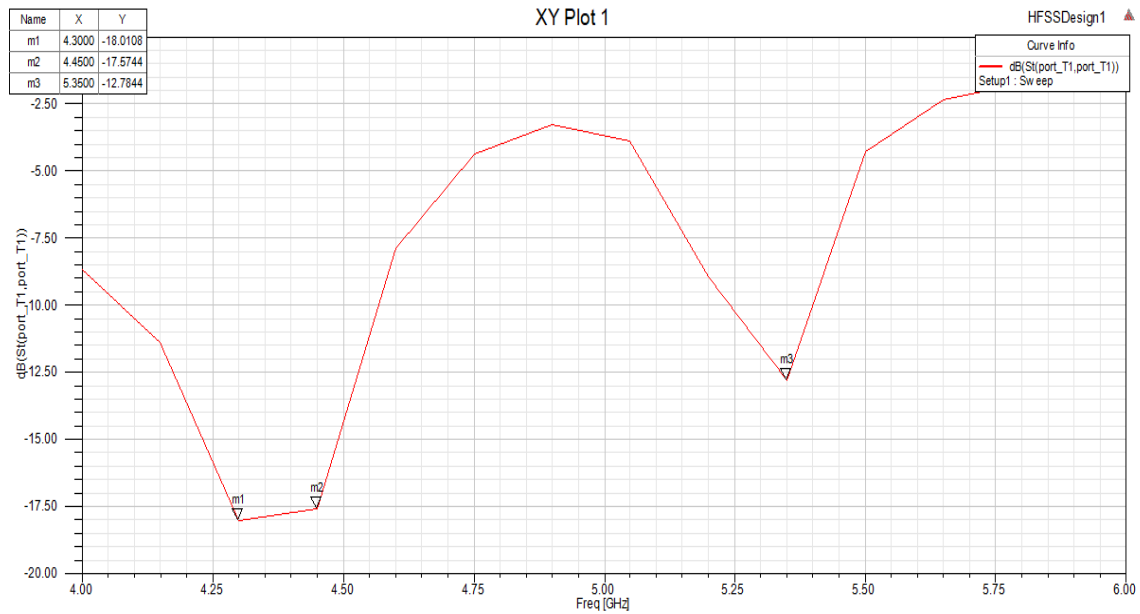


Figure 3. The return loss of the proposed antenna at 4.3 GHz is -18.01 dB as compared with circular antenna with a relative permittivity of 4.4

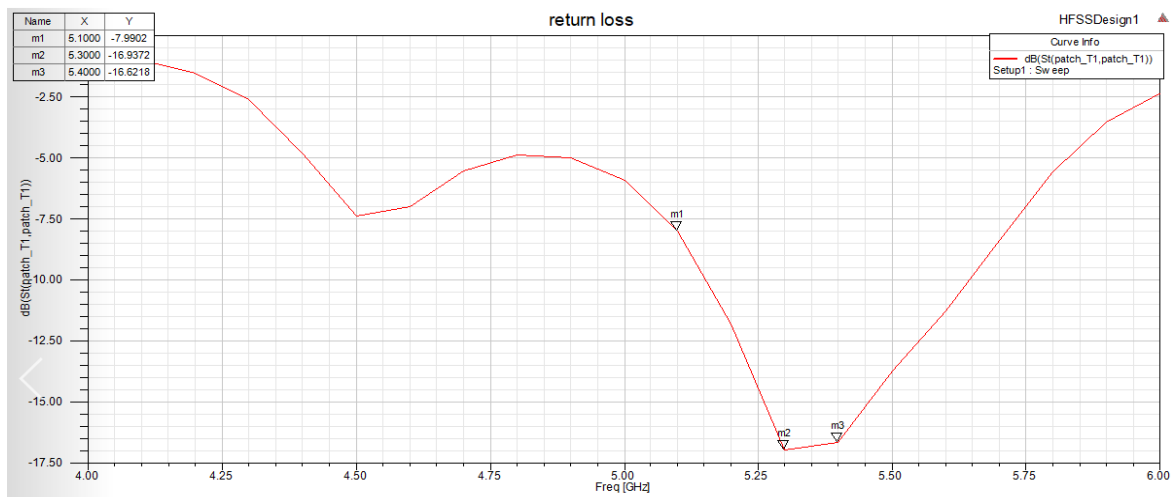


Figure 4. -16.9 dB of return loss is obtained with CPA for the resonating frequency of 5.3 GHz

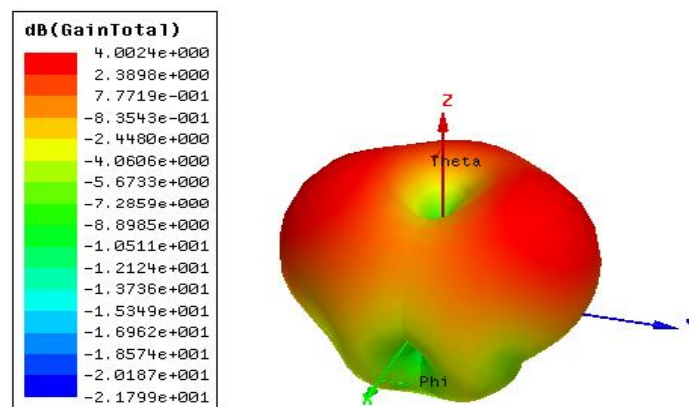


Figure 5. 7.7 dB of gain is obtained with an annular antenna for the resonating frequency of 4.3 GHz

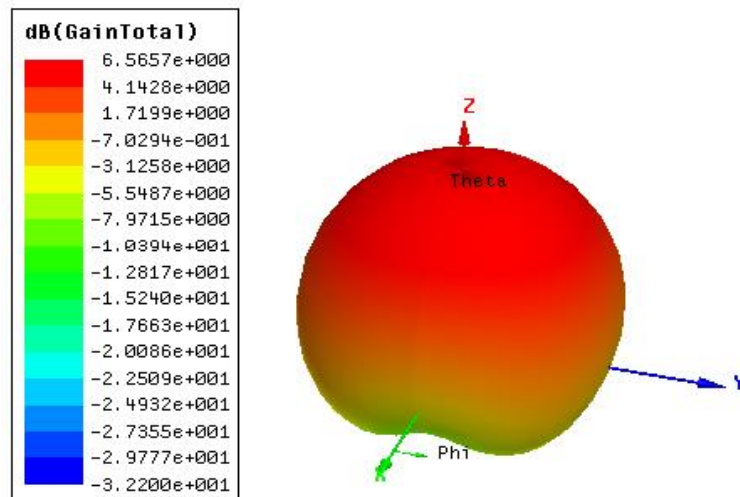


Figure 6. 6.5 dB of gain is obtained with an circular antenna for the resonating frequency of 5.3 GHz

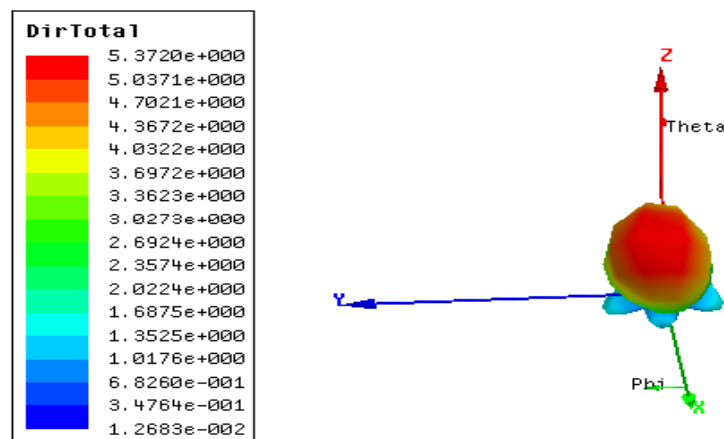


Figure 7. 5.37 dB of directivity is obtained during the design of annular tooth antenna which is more significant than the directivity of the existing circular patch

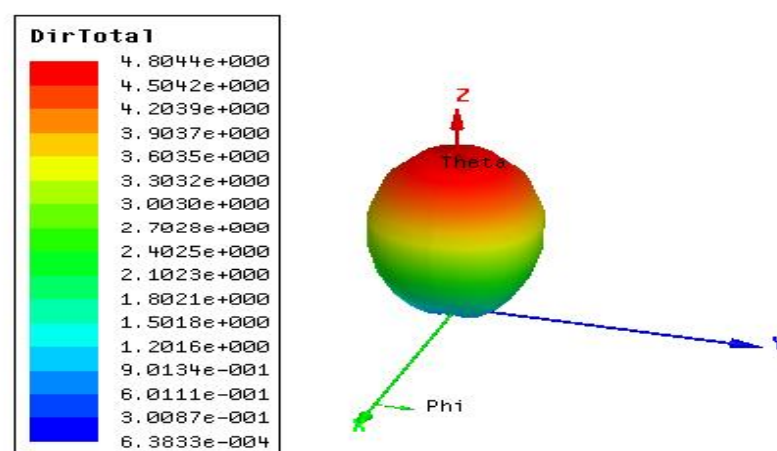


Figure 8. The directivity of the circular antenna is 4.8 dB which is less significant than the directivity of the proposed annular tooth antenna

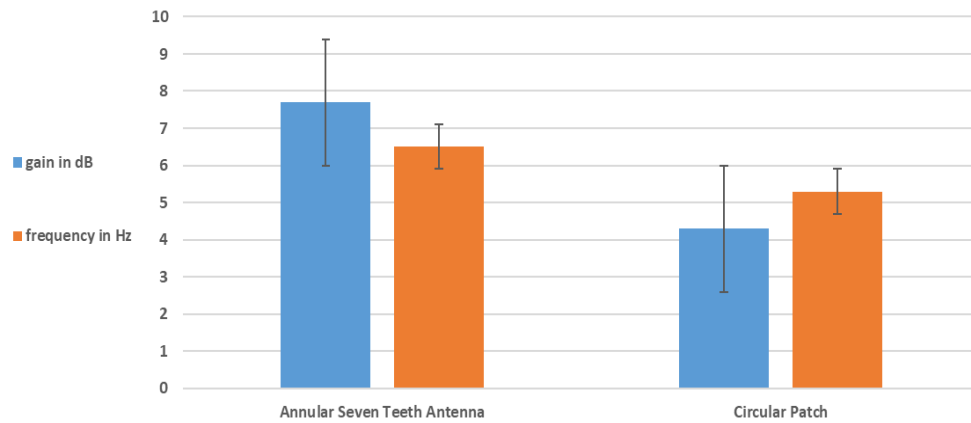


Figure 9. Barchart compares the mean gain of the annular tooth and circular antenna  
 \*Where, the annular antenna has a greater gain than the CPA. X axis: frequency and gain  
 Y axis: annular seven teeth antenna and CPA.

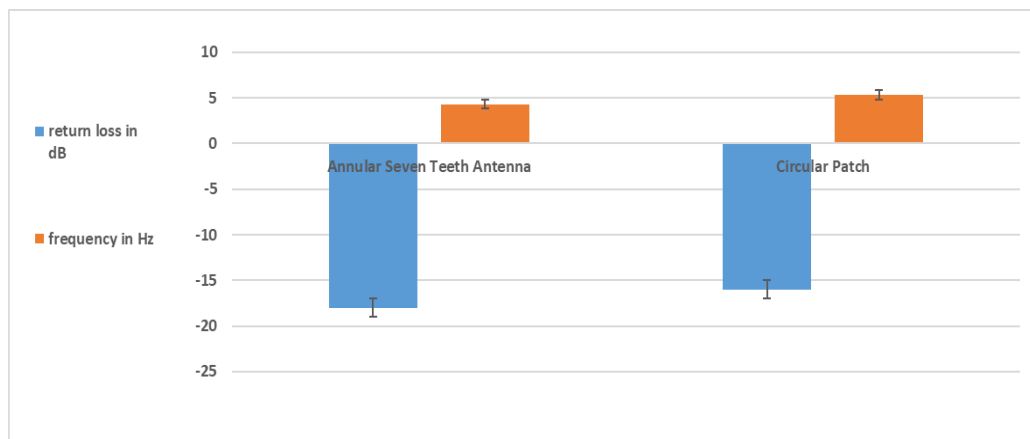


Figure 10. Barchart compares the mean of the return loss of the annular antenna and the existing antenna  
 \*Where, the proposed antenna has a more significant return loss value than the annular antenna.  
 X axis: frequency and gain Y axis: annular seven teeth antenna and CPA.

Table 1. Comparison of gain, return loss, directivity between novel annular seven tooth antenna and circular patch

Type of antenna	Frequency (GHz)	Gain (dB)	Return loss (dB)
Annular seven tooth antenna	4.3	7.7	-18
Circular patch	5.3	6.5	-16

\*All parameters are improved than circular patches

Table 2. The statistical parameters gain, return loss for array antenna and circular patch is obtained

Gain	Design groups	Sample (N)	Mean ( $\mu$ )	Standard deviation (SD)	Standard error mean (SME)
	Annular seven tooth antenna	19	1.6462	0.77307	0.11827
	Circular patch	19	4.0569	1.38027	0.34507

\*The mean of the circular array antenna is predominant to the circular patch

Table 3. Performance comparison with previously published work

Reference	No of elements	Complexity of design	Gain in dB	Return loss in dB
Proposed work	1	No	7.7	-18.1
[5]	1	Yes	3	-14.2
[12]	1	Yes	2.3	-20
[25]	1	Yes	5	-10

## 5. DISCUSSION

From the result it is observed that the return loss and gain of the novel annular seven tooth antenna for mobile navigation, satellite service application was 7.7 dB, -18 dB at 4.3 GHz and the substrate used in the design was FR4 epoxy. The gain, return loss of the proposed antenna is 7.7 dB, -18 dB. Since it uses line feed technique where the impedance matching is easy. As observed in the gain, return loss in curved microstrip line antenna is 7.990 dB and -81.399 dB [26]. Utilized is a Teflon substrate with a 4 mm thickness and a  $\epsilon_r=2.1$  dielectric constant. Two side-concave patches stimulate the circularly polarized radiation gain of 9.5 dB and frequency of 5.8 GHz constructed using the concatenated feed and identical patches and 0.3 dB axial ratio. The antenna is meant to be measured using a 180° phase shifter balun [25]. The return loss of 10 dB with the two parallel strip of dielectric material and improved strip length [27]. According to reports, CPA has a gain of 6 dB, which is comparable to the proposed antenna's gain and return loss. The thinness of the substrate, which is restricted to 1.6 mm, has a slight impact on the suggested antenna's effectiveness because it causes surface radiation. The goal for the future is to construct the antenna with minimized dielectric substrate thickness and improvised bandwidth for high biomedical imaging applications.

## 6. CONCLUSION

Novel annular seven tooth antenna for mobile navigation has better return loss and gain when compared with circular patch. The return loss and gain of -18.1 dB, 7.7 dB at 4.3 GHz radio frequency is obtained from the proposed antenna design when compared with the circular patch and it has a return loss and gain of -16 dB, 6.5 dB at 5.3 GHz radio frequency. The proposed antenna has magnificent gain, return loss and directivity. The proposed design has produced dual band when compared with circular antenna. The proposed work has better directivity which is used as directional antenna. Novel annular seven tooth antenna satisfies antenna parameter value and better output for navigation application.

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